smARTbox

Out-of-the-Box Technologies for Interactive Art and Exhibition

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ABSTRACT

Recent developments in the fields of interactive display technologies provide new possibilities for engaging visitors in interactive three-dimensional virtual art exhibitions. Tracking and interaction technologies such as the Microsoft Kinect and emerging multi-touch interfaces enable inexpensive and low-maintenance interactive art setups while providing portable solutions for engaging presentations and exhibitions. In this paper we describe the smARTbox, which is a responsive touch-enabled stereoscopic out-of-the-box technology for interactive art setups. Based on the described technologies, we sketch an interactive semi-immersive virtual fish tank implementation that enables direct and indirect interaction with visitors.

Categories and Subject Descriptors

I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism—*Virtual reality*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Artificial, augmented, and virtual realities*; J.5 [**Arts and Humanities**]: Arts, fine and performing

General Terms

Design, Human Factors

Keywords

Fish Tank Virtual Reality, Interactive Virtual Art, Multi-Touch, Scala, Actor, Swarm, School

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Laval Virtual VRIC'12, March 28-April 1, 2012 Laval, France
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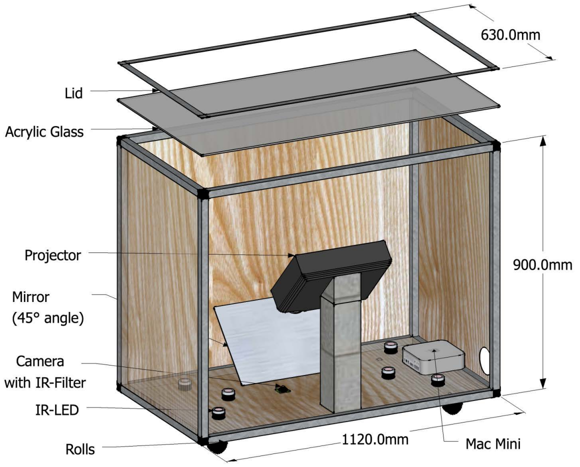

Figure 1: Schematic illustration of the smARTbox: a responsive out-of-the-box virtual reality art installation utilizing stereoscopic visualization based on back projection, and Rear-DI [22] for detection of multi-touch input.

1. INTRODUCTION

Interactive art is a relatively novel medium of installation-based art that involves the visitors in a way that allows the art to achieve its purpose [7]. Usually, interactive installations allow the visitor not only to view, but also to interact with the content. Exhibitions of this kind of art typically require displays and sensors to respond to visitors, for example to their motions, to heat, meteorological changes or other types of input, which their developer programmed them to respond to.

Virtual reality (VR) as a medium to present interactive experiences is becoming more and more attention for the field of fine art and exhibitions, not only because of the potential to immerse users in virtual art environments, but also for engaging them in natural or magical interactions [4] with virtual content that responds to the observer [7]. In particular, stereoscopic displays and visualization provide improved insight in three-dimensional (3D) art scenes in comparison to traditional monoscopic displays. This can be a strong emotional and esthetic factor for art installations. While interaction with virtual environments (VEs) in the field of VR development and design is traditionally enabled via extensive user instrumentation, e.g., with tracked 3D input devices or data gloves, for many interactive art environments it is essential that instrumentation of visitors is as unobstructive as possible.

In this context, recent developments of inexpensive while versatile body tracking systems, such as the Microsoft Kinect, vision-based tracking approaches [1, 30], and emerging multi-touch interfaces [22] have great potential for engaging one or several visitors in interactive art exhibitions without inconvenient instrumentation. It has been shown that in particular younger people have significantly less reservation against media technology and may be more engaged in interactive art installation than traditional exhibition [12].

When developing such interactive art exhibition, two technological aspects have to be considered: (i) the hardware setup, and (ii) the software implementation of interactive art content. Hence, usually a variety of people from different domains, for example, artists, designers, and computer scientists have to cooperate in an interdisciplinary way. A decisive role of such systems plays their software technical implementation. The used technologies largely affect the development process of new applications, as well as the maintainability of existing ones. Simulator X [17] is an alternative software platform for intelligent real-time interactive systems as found in the areas of virtual, augmented and mixed reality, as well as computer games. It uses novel approaches to software techniques and architectures and provides interactive art developers with a versatile and comparably easy-to-use platform.

Although costs and maintenance of VR systems has decreased over the past decades, many installations can only be used in highly specific application scenarios in some VR laboratories, whereas general applicability and portability, e.g., for exhibitions, is limited.

In this paper we introduce smARTbox - a responsive stereoscopic table setup that incorporates and encapsulates out-of-the-box technologies for portable art presentation and exhibition. The paper is structured as follows. Section 2 provides background information on unencumbering interaction with stereoscopically displayed virtual content within art setups. In section 3, we illustrate how the combination of a responsive multi-touch box with integrated user tracking and stereoscopic display can enrich fine art works by user interaction. In section 4, we sketch an application that shows the potential of the described platform for interactive art and exhibition. Section 5 concludes the paper.

2. BACKGROUND

In this section we describe the basic building blocks the smARTbox setup consists of in general, as well as related work in this fields. On this basis, section 3 then demonstrates their combination in the concrete implementation.

2.1 Stereoscopic Fish-Tank Visualization

Fish tank VR systems [19, 35] are considered as semi-immersive VR environments usually consisting of stereoscopic display technologies combined with head tracking to provide head-coupled perspective projections. Presenting stereoscopic views to visitors of interactive visual art environments can be a strong emotional and esthetic factor [18, 24], and thus is utilized by art designers in fish tank setups [23] following the "Window on a World" [9] metaphor. Such fish tank VR systems make use of (auto-) stereoscopic display technologies or projection screens combined with traditional desktop-, touch-based or 3D interaction. In contrast to expensive fully immersive VR setups, fish tank setups have enormous potential for visual arts since they are usually less expensive, easier to set up, calibrate and transport than fully immersive VR installations, i.e., semi-immersive setups can provide a portable solution for art presentation and exhibitions.

2.2 Tracking and Interaction

Recent advances in the field of markerless user tracking technologies, in particular, with developments in the entertainment sector, e.g., the Microsoft Kinect, lead to a broad range of new possibilities for interactive art design. Response generation in interactive display environments requires accurate real-time 3D information about the posture of one or multiple users, which has traditionally been limited in art installations due to issues of encumbering instrumentation and expensive equipment. With the reliable and inexpensive full-body skeleton tracking of the Microsoft Kinect it is now possible to get real-time 3D data about a user's head position and orientation that can be used in the process of stereoscopic rendering and presentation. In addition the gained information about the body and its pose allows art designers to build interactive content which is responsive to the body state and movements of the user [28, 29]. In particular, such semi-immersive 3D environments may respond dynamically to the presence, state, actions and behavior of visitors, which shape the virtual stimuli displayed to the users. Since multiple users can simultaneously be tracked and distinguished by the Kinect, this provides new possibilities for interactive collaborative art setups. Indeed, the Kinect provides real-time 3D information about the positions and orientations of the arms and hands of tracked users. However, the data represents only approximations, which are usually limited in accuracy and precision and therefore are often not sufficient for direct input.

2.3 Direct Interscopic Touch Input

As mentioned above, 3D content often benefits from stereoscopic visualization and interaction. However, many elements that require accurate input in graphical user interfaces do not have associated depth, but appear two-dimensional. Interactions between mono- and stereoscopic elements, i.e., interscopic interaction techniques [27], have to be considered for the interrelations between elements displayed with different, stereoscopic parallax on a display surface. In this context, multi-touch interaction has recently received considerable attention [25] due to the potential of comparably accurate input, and near-natural interaction with mono- and stereoscopic objects relative to display surfaces [32, 33]. Multi-touch surfaces support input with multiple fingers and/or hands [5], which can be realized with various technologies, such as capacitive sensing or analysis of infrared or color images [34]. In particular, touch-enabled setups

Figure 2: Photo taken of our touch-enabled prototype (the perspective was registered with the camera for the photo).

based on frustrated total internal reflection (FTIR) [15] or diffused illumination (DI) [22] have shown their potential over the last years, and fostered developments of multi-touch setups due to their low costs. Although touch-input is limited by the physical constraints of the touch surface, users do not have to use obstructive devices for interaction, such that these technologies can provide an unencumbering solution for intuitive and natural interaction. The ability to directly touch graphical elements while getting passive haptic feedback [14] with collocated or augmented visual-motor responses about touch interactions from the touch surface has been shown to be very appealing for novice as well as expert users [3], and has the potential to improve interaction in fish tank VR setups [31]. Multi-touch devices with non-planar touch surfaces, e.g., cubic [8] or spherical [2], have been proposed, which could be used to specify 3D axes or points for indirect object manipulation.

3. INTERACTIVE ART INSTALLATION

In this section we describe the responsive touch-enabled stereoscopic display setup, which supports direct and indirect interaction with visitors.

Our semi-immersive fish tank VR setup combines three main components in the frame of a portable 63 cm × 112 cm × 90 cm box:

- Stereoscopic visualization based on the "Window on a World" [9] metaphor using a table-top passive back projection screen,
- multi-finger and multi-hand touch-input based on the Rear-DI [22] principle, and
- Kinect full-body user tracking [28].

A schematic of the system is illustrated in Figure 1. Figure 2 shows a photo taken of a user interacting with our prototype. The hardware setup was constructed at a total cost of less than $4,000.

3.1 Window on a World

The top side of the table consists of a 62 cm × 112 cm back projection screen with a gain of 1.6, allowing a bright display for a large range of viewing angles. For stereoscopic display on the back projection screen we use an Optoma GT720 projector with a resolution of 1280 × 800 pixels at a refresh rate of 120 Hz, which supports active stereoscopic display with inexpensive DLP-based shutter glasses. The projector is supplementary equipped with a wide-angle converter lens. The image is projected from the projector in the base of the table to the back projection screen via a mirror that is mounted at an angle of 45°. The left and right eye of a user receive different views to the same virtual scene rendered from slightly different perspectives which are generated from the eye positions of the viewer in front of the display surface. Using active shutter glasses, the images are displayed frame-sequentially to the eyes of a user with a rate of 60 Hz per eye. The stereoscopic display allows the rendering of virtual content with different stereoscopic parallax, i.e., negative, zero or positive parallax, resulting in objects appearing in front, on top, or behind the display surface. This enables out-of-box interaction concepts as described in section 4. The virtual environment is rendered on an Intel Core i7 computer with 3.40 GHz processor, 8 GB of main memory, and nVidia Quadro 4000 graphics card.

3.2 Multi-touch Interaction

The back projection screen at the top of the smARTbox is enhanced to a horizontal touch-sensitive input surface via the Rear-DI principle [22]. Using this approach, infrared (IR) light has to illuminate the screen from behind the touch surface. This is achieved by six clusters of high-power IR LEDs, which are arranged inside the box. Since the projection screen consists of a diffusing material, it suffices for illumination using Rear-DI, without the requirement for an additional diffusing layer.

In the case an object comes in contact with the surface, e.g., a finger or palm, it reflects the IR light, which then is sensed by a camera equipped with an IR filter. Therefore, a PointGrey Dragonfly2 digital video camera with a wide-angle lens and infrared band-pass filter is mounted at a distance of ca. 90 cm from the projection screen, which captures 8-bit monochrome images with a resolution of 1024 × 768 pixels at an update rate of 30 frames per second. We use a modified version of the NUI Group's CCV software for detection of touch gestures [6].

3.3 Kinect Body Tracking

As illustrated in Figure 2, we make use of a Microsoft Kinect and the flexible action and articulated skeleton toolkit (FAAST) for real-time tracking of users interacting with the setup [28]. The Mictosoft Kinect is a multi-sensor system based on projecting a structured IR light pattern into the scene, which is captured by the integrated IR camera, and used to reconstruct the distance of points in space [10, 21]. The data provided by the Kinect sensor includes an RGB image with a resolution of 1280 × 1024 pixels at a refresh rate of 15 Hz with 63° horizontal and 50° vertical field of view (FOV), an IR image of 1280 × 1024 pixels again at 15 Hz with a 57° horizontal and 45° vertical FOV, as well as a computed depth image of 640 × 480 pixels at 30 Hz [16]. The Kinect also supports a 640 × 480 pixels reduced versions of RGB and IR images running at 30 Hz.

FAAST utilizes the described multi-sensor to allow us to track the approximated head position and orientation of a user, which can then be used to provide head-coupled rendering, and the generation of stereoscopic views. Full-body skeletal information of users is tracked to provide computer-generated art environments with the ability to develop visualizations based on user-aware virtual content, i.e., reacting and responding to actions and the state of the user's body. The tracking however is bound to the limitations of FAAST and the Microsoft Kinect in terms of distance and occlusions. Section 5 references future work, that is destinated to solve this problem for the smARTbox setup.

3.4 Software Setup

The software setup is based on Simulator X [17], a software platform for intelligent realtime interactive systems, which was developed from the SIRIS[1] project. Simulator X provides a state-of-the-art unified and scalable concurrent programming paradigm for intelligent interactive applications. The platform uses an extensible entity model in combination with loosely coupled components as building blocks of applications. By conceptually dividing the architecture into different, accessible layers dedicated to core, component and application developers, Simulator X addresses many application requirements as well as user experience. It is portable to all major desktop and many mobile computing platforms. The use of the Scala language incorporates modern functional language constructs as well as object oriented concepts. Due to the compatibility between Scala and Java the wide variety of available Java libraries can be used for applications. Simulator X already contains components for rendering, physics, sound and the handling of typical VR input devices.

In the out-of-the-box setup, sensor data is processed, and provided to a concurrently running interactive art simulation to handle possible responses in the virtual world. In addition, virtual views are periodically rendered, using stereoscopic quad-buffering and off-axis frustums to provide binocular views to the user.

4. RESPONSIVE VIRTUAL FISH TANK

In this section we describe a virtual fish tank simulation, which showcases the affordances of the smARTbox setup. Users can intuitively interact with the virtual simulation in an unobstructive way by using only their body, in particular their hands (see Figures 2 and 3).

As described in section 2, we make use of a VR fish tank metaphor and decided to implement a virtual fish tank to underline the out-of-the-box idea of the smARTbox. As illustrated in Figure 2, the general concept is to display a virtual fish tank on the smARTbox in such a way that the water world appears stereoscopically with positive parallax inside the box, whereas the water is displayed with almost zero parallax at the touch surface, and thereby provides the illusion of the affordance of touching water. The touch-sensitive surface separates the virtual fish tank from the real world outside the box. Negative stereoscopic parallax effects would allow designers to display objects even above the surface, for instance a jumping fish.

Figure 3: Virtual fish tank simulation: The fishes and the water surface are reacting to the presence of the user's hand

4.1 The Artwork

In our work the user is designed as a phenomenon of nature that is invading a microcosm inhabited by artificial virtual life forms. While the computer-generated entities are modeled in discrete microstructures with individual characteristics, state, and behavior, the motion of a swarm of entities forms a visually complex pattern that appears magnificently fluid and synchronized.

A central aspect of the virtual fish tank application is the self-sufficient and user-reactive simulation of virtual fish behavior. In nature, fishes show a school behavior, on which our simulation is based. We use a general and distributed model of behavior [20], which will be briefly explained in the following section.

The exact movement of a school is a very complex occurrence in nature. A single fish acts independently of other school members, while the behavior of the school as a whole results from the behavior of each single fish and is not globally synchronized. It is assumed that the concrete behavior of a single fish is based only on its perception of the environment. To simulate school behavior, we simulate the perception and the inferred behavior for each fish as well as the effects on the virtual world. To create a connection between the user in the real world and the simulated fishes in the virtual world, we include the user into the perceivable environment of the fishes.

The behavior of a single fish in the fish tank application results from its coordination with other members of the school, as well as transient interests. The main interests are collision avoidance and the urge to stay close to the school. This is represented by three prioritized rules [20]:

- Collision Avoidance: avoid collisions with nearby school-mates.
- Velocity Matching: attempt to match velocity with nearby school-mates.
- School Centering: attempt to stay close to nearby school-mates.

Every rule produces a suggestion in terms of an acceleration vector how the fish could possibly move. The suggestions are then processed to calculate an actual acceleration vector for every fish by applying prioritized acceleration allocation [20]. A physics component uses this acceleration vectors

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[1] Semantic Reflection for Realtime Interactive Systems

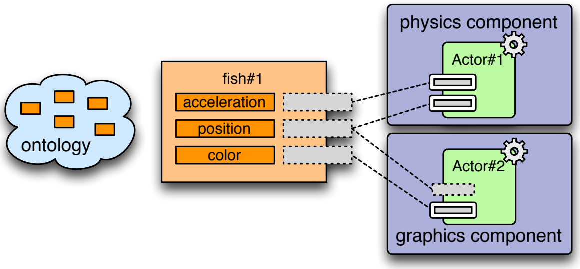

Figure 4: The Simulator X enity model. Ontology-based annotations are used to define the semantics of entity attributes. The attributes are interpreted by components build of actors.

to simulate the fish movement. For the presented fish tank application we expanded the three basic rules in order to connect the user behavior with the fish behavior. We simulate user interaction as attractors or detractors to virtual fish, e.g., by modeling attractant and repellent points which the fishes approach or avoid. These points are created, for instance, when the user gets in close contact to the pane of the virtual fish tank.

Besides the simulation of the fish behavior, our fish tank application provides a user-reactive water surface to support the user's sense of feeling present in the space of the virtual fish simulation. A detected point of contact of a user's hand or finger with the pane of the fish tank causes a stimulation of the water surface at that point. The interactive art simulation processes these events, and a corresponding rippling effect of the water surface is rendered and displayed.

4.2 Implementation

The conceptual design of the implementation is divided into three subsystems: Two sensor modules that collect and process the sensor data from the Microsoft Kinect as well as from the touch-sensitive surface, and a main application based on Simulator X to create the virtual fish tank environment and to handle the school logic of the fish simulation.

Simulator X thereby serves as a software platform providing mechanisms to execute and connect services, which are periodically accessed by the application (e. g., rendering or physics). To achieve this, Simulator X uses the actor model [11] as a basis for higher-level concepts, such as a unified entity model, a loosely coupled component model and an event system, all of which support ontology-based semantic annotations [17] (see Figure 4).

To realize the virtual fish tank as described above, the following aspects are implemented using Simulator X's component model: Graphical rendering, simulation of the fish behavior, physical simulation, sound rendering, key-frame animations, and handling of the refined sensor input.

The current version of Simulator X already includes components for graphical rendering (based on JOGL), physical rendering (based on jBullet), sound rendering (based on lwjgl) and key-frame animation (based on Cal3D). These components were designed to enable fast application development, while satisfying typical design requirements.

The water simulation and graphical rendering is realized on the GPU by implementing new shader programs as well as by configuring the existing graphics component. To support the out-of-the-box idea presented in this paper, we used a pragmatic approach to model the water surface as a grid of masses connected to springs. More complex simulations of water surfaces are typically very time-consuming in implementation, and may be used to upgrade the application if needed.

Figure 5: A responsive virtual fish tank implementation using the plattform “living surface”, a commercial product from the Vertigo Systems GmbH.

The simulation of the fish behavior required the implementation of a new component. This school-component is based on Reynolds' distributed behavior model [20] and uses Simulator X's actor model to realize the individual behavior of single fishes. In addition the provided entity model and the ontology-based semantic annotations are used to describe the behavior of the fishes individually and embed detected user movements to the simulation. By doing so, the overall component architecture maintains easy exchangeability and expandability of fish behaviors as well as of entire sub-modules, such as the required neighborhood calculation.

The components are connected to a main application using the provided Simulator X methods. In this process required components are created and configured, entities are created and linked to the components, and the handling of input data is set up. By using the Simulator X platform as basis for the virtual fish tank, two major advantages arise: Simulator X's architecture supports high cohesion and a low coupling, resulting in high maintainability, exchangeability and scalability. The component model in conjunction with the already provided components allows the virtual fish tank to be easily ported to other setups like CAVEs or wall mounted scenarios (see Figure 5).

5. CONCLUSION

In this paper we introduced the smARTbox, a portable semi-immersive art installation that combines out-of-the-box technologies for art presentation and exhibition, which do not require expensive tracking or display technologies. We described the technologies encased in the setup, and sketched a virtual fish tank simulation that makes use of the affordances provided by the smARTbox for engaging users in a VE.

In the future we plan to improve the display and tracking capabilities of the smARTbox: For example the tracking via FAAST could be extended to cover close distance scenarios where parts of the user's body (likely the user's legs) are occluded. Additionally the overall immersiveness could be strengthened by incorporating an additional touch-sensitive projection screen in the front side of the table, and by enhancing the visual quality of the presented fish tank simulation with responsive fluid dynamics [13] and virtual reflections of visitors [26].

6. ACKNOWLEDGMENTS

The authors of this work are supported by the Deutsche Forschungsgemeinschaft (DFG 29160962), and by the German Federal Ministry of Education and Research, program IngenieurNachwuchs, project SIRIS (#17N4409). Furthermore the authors want to thank the Vertigo Systems GmbH for their cooperation and support in the design of the responsive virtual fish tank simulation.

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